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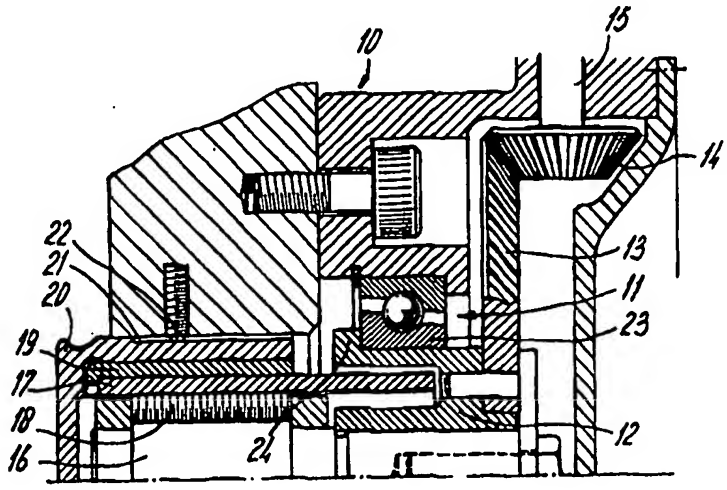
(54) Title: ACTUATOR HAVING IMPROVED ACCURACY



(57) Abstract

An actuator comprises a housing (1, 10), a motor, an actuating member and a screw mechanism providing a linear movement of the actuating member with respect to the housing (1, 10) in response to a rotational movement of the motor, said screw mechanism comprising a screw (5, 16) and a nut (1, 17) at least one of which is rotatably supported with respect to the housing (1, 10) by means of a rolling element bearing (2, 11), said rolling element bearing (2, 11) having an inner raceway (6) and an outer raceway (6), as well as rolling elements which are in rolling contact with said raceways. At least one of the components of the screw mechanism, e.g. the screw (5, 16), nut (1, 17) or rollers (4, 16) and/or at least a component of the bearing (2, 11), e.g. the inner bearing ring or the outer bearing ring, comprises a surface part which is manufactured by means of a hard cutting operation, e.g. hard turning, hard milling, hard drilling, etc.

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Actuator having improved accuracy

The invention is related to an actuator comprising a housing, a motor, an actuating member and a screw mechanism providing a linear movement of the actuating member with respect to the housing in response to a rotational movement of the motor, said screw mechanism comprising a screw and a nut at least one of which is rotatably supported with respect to the housing by means of a rolling element bearing, said rolling element bearing having an inner raceway and an outer raceway, as well as rolling elements which are in rolling contact with said raceways.

Such actuator is known. It can be applied for various purposes, e.g. for a brake calliper of a disc brake. The actuator comprises several components with accurately machined surfaces. such as the threads in the screw and nut, rollers, bearing raceways etc. A considerable part of the total costs of the actuator therefore is to be attributed to the machining process.

Attempts have been made to reconcile the demands of accuracy on the one hand, and low manufacturing costs on the other hand. The invention aims at providing an actuator wherein both demands are satisfied. This aim is achieved in that at least a component of the screw mechanism, e.g. the screw, nut or rollers and/or at least a component of the bearing, e.g. the inner bearing ring or the outer bearing ring, comprises a surface part which is manufactured by means of a hard cutting operation, e.g. hard turning, hard milling, hard drilling etc.

The accuracy of the displacements of the actuator in response to control signals depends to a large extend on the engagement of the several surfaces of the screw mechanism and the bearings. The screw threads of nut and screw and the interposed rollers, and also the raceways of the bearings play a decisive role in this respect. Also the accuracy concerning the mutual position of these surfaces is of importance. By means of a hard cutting process, these surfaces may be integrated in the screw or nut providing an inherent accuracy, which is not influenced by accumulated manufacturing tolerances which play a role in assembled, multiple part constructions.

Hard turning is a single point cutting process for machining hardened steel components. It can be considered as an advantageous alternative to both rough grinding and finish grinding. Said process of hard turning is carried out by means of

ceramic or superabrasive tools. It is particularly suitable for combining reduced production costs and proper finish, as only one production step is sufficient for obtaining the required finish.

Moreover, the integrated surfaces can conveniently be manufactured by means of a multiple-spindle lathe, which offers advantages both with respect to accuracy and costs (production speed).

The bearing may support the screw directly or indirectly. Furthermore, the hard turned surface part may be applied for radial support of the screw mechanism. Also, said surface part may be applied for axial support of the screw mechanism.

According to a further possibility, the actuator may comprise a gear reduction mechanism connected to the screw mechanism, said gear reduction mechanism, comprising a surface part which is manufactured by means of a hard cutting operation, e.g. hard turning, hard milling, hard drilling etc.

Additionally, at least a component of the screw mechanism, e.g. the screw, nut or rollers, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring, and/or of the gear reduction mechanism, may comprise a surface part which is manufactured by means of grinding.

Also, at least a component of the screw mechanism, e.g. the screw, nut or rollers, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring, and/or of the gear reduction mechanism, may comprise a surface part which is manufactured by means of broaching.

By means of the hard turning process, it is also possible to manufacture integrated parts of the screw, nut etc. of the actuator. For instance, by means of this process, a groove for accommodating a seal or shield may be manufactured in the inner ring and/or the outer ring. Moreover, the nut or screw may be provided in this way with drive means, e.g. splines, gears or teeth, for direct or indirect engagement with a drive source.

In particular, at least one of the components may comprise a surface part, e.g. a screw thread, which is obtained by the subsequent manufacturing steps of cold forging, and/or cold rolling, soft turning, and hardening followed by hard turning.

Alternatively, at least part of at least one of the components, e.g. the functional surfaces such as bearing raceway may be treated for surface modification, e.g. by lapping or by applying a diamond-like coating.

Also, at least part of at least one of the components may be obtained from a sintered powder material.

Furthermore, at least part of at least one of the components may comprise a through- or case-hardened material obtained by a quenching process using oil, salt or spray quenching techniques or surface hardening using coating techniques.

Furthermore, at least part of at least one of the components, e.g. the raceway may be treated by induction surface hardening using polymer or spray quenching techniques.

The bearing in question may be a four-point contact ball bearing or a roller bearing e.g. a cylindrical needle or taper roller bearing.

The reduction gear mechanism may engage either the screw or nut of the screw mechanism.

In this respect, the screw or nut may comprise a (additional) raceway for a reduction gear means support bearing, said reduction gear means engaging both the screw mechanism and a drive source.

According to a first possibility, the nut is rotatably supported with respect to the housing by means of a rolling element bearing, the inner ring of said bearing forming a unity with the nut or engaging a reference face on the nut.

According to a second possibility, the screw is rotatably supported with respect to the housing by means of a rolling element bearing, the inner ring of said bearing forming a unity with the nut or engaging a reference face on the nut.

Several types of steel may applied for the components which are obtained by means of a hard-cutting operation. Examples of these steel types are carburizing steel, forged steel, powder formed steel, rolled steel, cast steel, tool steel, forged steel etcetera.

The invention is also related to a method for manufacturing an actuator according to any of the preceding claims, said actuator comprising a housing, a motor, an actuating member and a screw mechanism providing a linear movement of the actuating member with respect to the housing in response to a rotational movement of the motor, said screw mechanism comprising a screw and a nut one of which is rotatably supported with respect to the housing by means of a rolling element bearing, said rolling element bearing having an inner raceway and an outer raceway, as well as rolling elements which are in rolling contact with said raceways.

According to the invention, said method comprises the step of manufacturing a surface part of at least a component of the screw mechanism, e.g. the screw, nut, cage, cam, roller or ball, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring, by means of a hard cutting operation, e.g. hard turning, hard milling, hard drilling etc.

Furthermore, said method may comprise the step of manufacturing a surface part of at least a component of the gear reduction mechanism by means of a hard cutting operation, e.g. hard turning, hard milling, hard drilling etc.

Additionally, the method may comprise the step of manufacturing a surface part of at least a component of the screw mechanism, e.g. the screw, nut, cage, cam, roller or ball, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring, and/or of the reduction gear mechanism, by means of grinding.

Also, the method may comprise the step of manufacturing a surface part of at least a component of the screw mechanism, e.g. the screw, nut or roller, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring and/or of the gear reduction mechanism, by means of broaching, and/or the step of manufacturing an inner raceway for said bearing, or a reference face for an inner bearing ring, in at least the screw or the nut.

The hard cutting operation can be carried out by means of a cutting head having at least two simultaneously active cutting tips. By applying a cutting tool with multiple cutting tips, a rapid manufacturing operation is made possible.

The invention will be described further with reference to the embodiments shown in the figures.

Figure 1 shows part of a first embodiment of the screw actuator.

Figure 2 shows part of a second embodiment of the screw actuator.

The actuator shown in figure 1 comprises a nut 1, which by means of bearing 2 is rotatably supported in housing part 3. By means of rollers 4, the nut engages a screw 5. By rotating nut 1, screw 5 is displaced in axial direction. The rollers are accommodated in a cage 30, as is known per se.

According to the invention, several surfaces of this actuator have been manufactured by means of a hard cutting operation. For instance, the raceway 6 of the bearing 2, which raceway 6 is integrated in the nut 1, is obtained by a hard

turning operation. Also the screw thread 7 of the screw can be manufactured by a hard cutting operation.

Moreover, the rollers 4 and the internal screwthread of the nut can be obtained in this way.

The nut may comprise a further raceway 8, also provided by means of a hard turning operation. This raceway 8 can be used for a needle bearing, e.g. for supporting further actuator parts such as a reduction gear mechanism.

The actuator according to figure 2 comprises a housing 10 which carries the thrust bearing 11. The thrust bearing 11 supports a sleeve 12, connected to tooth gear 13 which is driven by a gear transmission e.g. bevel gear 14. Gear 14 is connected to a motor (not shown) by means of shaft 15.

The sleeve 12 in turn is connected to screw 16. This screw 16 can be rotated by means of the gear wheels 13, 14, but cannot move axially.

Upon rotating the screw, nut 17 is moved axially through the rollers 18. Nut 17 in turn is connected to piston 20 by means of intermediate sleeve 19.

Piston 20 has an external, axial groove 21, engaging a projection 22 accommodating in housing 10. Thus, piston 20, and thereby nut 17, is able to move axially, but cannot rotate.

Several surfaces of the actuator according to figure 2 are obtained by a hard-cutting operation. As in the actuator according to figure 1, the screwthread of screw 16, nut 17, as well as the rollers 18 may be obtained by e.g. hard turning. Also, reference face 23 on flange 24 of sleeve 12, which reference face 23 defines the position of bearing 11, can be obtained in this way.

Claims

1. Actuator, comprising a housing (1, 10), a motor, an actuating member and a screw mechanism providing a linear movement of the actuating member with respect to the housing (1, 10) in response to a rotational movement of the motor, said screw mechanism comprising a screw (5, 16) and a nut (1, 17) at least one of which is rotatably supported with respect to the housing (1, 10) by means of a rolling element bearing (2, 11), said rolling element bearing (2, 11) having an inner raceway (6) and an outer raceway, as well as rolling elements which are in rolling contact with said raceways, characterized in that at least one of the components of the screw mechanism, e.g. the screw (5, 16), nut or rollers (5, 18) and/or at least a component of the bearing, e.g. the inner bearing ring or the outer bearing ring, comprises a surface part which is manufactured by means of a hard cutting operation, e.g. hard turning, hard milling, hard drilling etc.

2. Actuator according to claim 1, wherein said surface part is for radial support of the screw mechanism.

3. Actuator according to claim 1 or 2, wherein said surface part is for axial support of the screw mechanism.

4. Actuator according to claim 1, 2 or 3, comprising a gear reduction mechanism connected to the screw mechanism, which gear reduction mechanism comprises a surface part which is manufactured by means of a hard cutting operation, e.g. hard turning, hard milling, hard drilling etc.

5. Actuator according to according to the preceding claims, wherein at least a component of the screw mechanism, e.g. the screw, nut or rollers, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring, and/or of the gear reduction mechanism, comprises a surface part which is manufactured by means of grinding.

6. Actuator according to any of the preceding claims, wherein at least a component of the screw mechanism, e.g. the screw, nut or roller, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring, and/or of the gear reduction mechanism, comprises a surface part which is manufactured by means of broaching.

7. Actuator according to any of the preceding claims, wherein at least one of the components comprises a surface part, e.g. a screw thread, raceway, reference face or teeth, which is obtained by the subsequent manufacturing steps of cold forging, cold rolling, soft turning, hardening followed by hard turning.

8. Actuator according to any of the preceding claims, wherein at least part of at least one of the components, e.g. the functional surfaces such as a bearing raceway, is treated for surface modification, e.g. by lapping or by applying a diamond-like coating.

9. Actuator according to any of the preceding claims, wherein at least part of at least one of the components is obtained from a metallic or non-metallic material or sintered powder material.

10. Actuator according to any of the preceding claims, wherein at least part of at least one of the components comprises a through- or case-hardened material obtained by a quenching process using oil, salt, gas or spray quenching techniques or surface hardening using coating techniques.

11. Actuator according to any of the preceding claims, wherein at least part of at least one of the components, e.g. the bearing raceway, is treated by induction surface hardening using polymer, gas or spray quenching techniques.

12. Actuator according to any of the preceding claims, wherein the inner raceway of said bearing, or a reference face for engagement with an inner bearing ring which comprises said inner raceway, is integrated in the nut or screw.

13. Actuator according to claim 12, wherein the nut is rotatably supported with respect to the housing (4) by means of a rolling element bearing, the inner ring of said bearing forming a unity with the nut or engaging a reference face on the nut.

14. Actuator according to claim 12 or 13, wherein the screw is rotatably supported with respect to the housing (4) by means of a rolling element bearing, the inner ring of said bearing forming a unity with the nut or engaging a reference face on the nut.

15. Actuator according to any of the preceding claims, wherein the inner ring and/or the outer ring comprises a groove for accommodating a seal or shield.

16. Actuator according to any of the preceding claims, wherein the nut or screw comprises drive means, e.g. keyslot, splines, gears or teeth, for direct or indirect engagement with a drive source.

17. Actuator according to any of the preceding claims, wherein the bearing is a ball bearing e.g. four-point contact ball bearing or taper roller bearing e.g. needle roller bearing, cylindrical bearing or taper roller bearing.

18. Actuator according to any of the preceding claims, wherein the screw mechanism is driven through a reduction gear mechanism engaging the screw or nut.

19. Actuator according to any of the preceding claims, wherein the screw or nut comprises a (additional) raceway for a reduction gear means support bearing, said reduction gear means engaging both the screw mechanism and a drive source.

20. Actuator according to any of the preceding claims, wherein the screw mechanism comprises a ball screw or a roller screw.

21. Actuator according to any of the preceding claims, wherein at least one of the components of the screw mechanism and/or of the bearing comprises a carburizing steel.

22. Actuator according to any of the preceding claims, wherein at least one of the components of the screw mechanism and/or of the bearing comprises a forged steel.

23. Actuator according to any of the preceding claims, wherein at least one of the components of the screw mechanism and/or of the bearing comprises a powder formed steel.

24. Actuator according to any of the preceding claims, wherein at least one of the components of the screw mechanism and/or of the bearing comprises a rolled steel.

25. Actuator according to any of the preceding claims, wherein at least one of the components of the screw mechanism and/or of the bearing comprises a cast steel.

26. Actuator according to any of the preceding claims, wherein at least one of the components of the screw mechanism and/or of the bearing comprises a tool steel.

27. Method for manufacturing an actuator according to any of the preceding claims, said actuator comprising a housing, a motor. an actuating member and a screw mechanism providing a linear movement of the actuating member with respect to the housing in response to a rotational movement of the motor, said screw mechanism comprising a screw and a nut one of which is rotatably supported with respect to the housing by means of a rolling element bearing, said rolling element bearing having an inner raceway and an outer raceway, as well as rolling elements which are in rolling contact with said raceways, characterized by the step of manufacturing a surface part of at least a component of the screw mechanism, e.g. the screw, nut, cage, cam, roller or ball, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring, by means of a hard cutting operation, e.g. hard turning, hard milling, hard drilling etc.

28. Method according to claim 27 for manufacturing an actuator according to claim 4, comprising the step of manufacturing a surface part of at least a component

of the gear reduction mechanism by means of a hard cutting operation, e.g. hard turning, hard milling, hard drilling etc.

29. Method according to claim 27 or 28, comprising the step of manufacturing a surface part of at least a component of the screw mechanism, e.g. the screw, nut, cage, cam, roller or ball, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring, and/or of the reduction gear mechanism, by means of grinding.

30. Method according to any of claims 27-29, comprising the step of manufacturing a surface part of at least a component of the screw mechanism, e.g. the screw, nut or roller, and/or of the bearing, e.g. the inner bearing ring or the outer bearing ring and/or of the gear reduction mechanism, comprises a surface part which is manufactured by means of broaching.

31. Method according to any of claims 27-30, comprising the step of manufacturing an inner raceway for said bearing, or a reference face for an inner bearing ring, in at least the screw or the nut.

32. Method according to any of claims 17-31, wherein the hard cutting operation is carried out by means of a cutting head having at least two simultaneously active cutting tips.

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Fig - 1

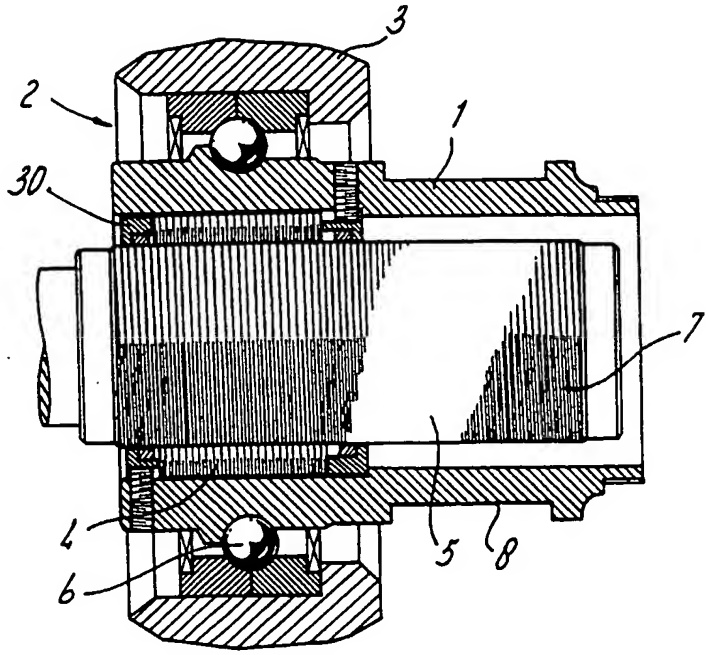
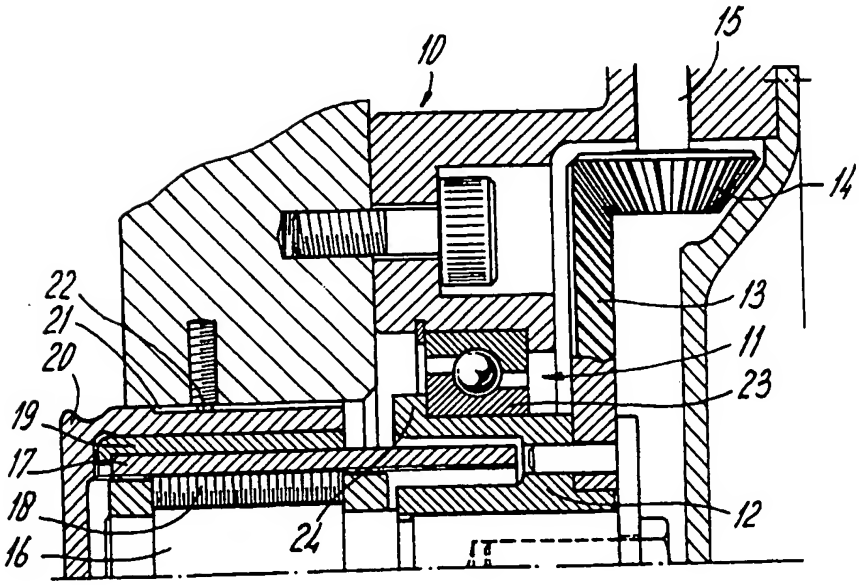


Fig - 2



INTERNATIONAL SEARCH REPORT

Inter nal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H02K7/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H02K F16D F16C B23B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	HASAN RIZWAN: "Why are you still grinding?" MANUF ENG;MANUFACTURING ENGINEERING FEB 1998 SME, DEARBORN, MI, USA, vol. 120, no. 2, February 1998, XP002087491 see page 76 - page 80 --- -/--	1-5, 7-11,13, 16-20, 27-29,31

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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